Alabama Water Resources Research Institute Annual Technical Report FY 2016

Introduction

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Introduction The Alabama Water Resources Research Institute (AL WRRI) was created in 1964 by the Alabama Legislature. In 2007, the AL WRRI was combined with the newly created Auburn University Water Resources Center (AU WRC) and in 2008 it was designated as part of the Auburn University Center of Excellence for Watershed Management. In 2013, the AU WRC and the AL WRRI were re-organized and funded under the auspices of Auburn University's Alabama Agricultural Experiment Station (AAES) and the Alabama Cooperative Extension System (ACES). The mission of the AU WRC is to facilitate successful collaboration among Auburn University faculty and staff on multidisciplinary water-related research, outreach, and teaching; and to facilitate the active involvement of private citizens in the stewardship of water resources.

The AL WRRI is one of 54 water resources institutes nationwide authorized by the federal Water Resources Research Act and retains membership in the National Institutes for Water Resources (NIWR). The AL WRRI serves the state of Alabama at large in administering the funding provided under the Water Resources Research Act that is administered by the US Geological Survey. The NIWR program provides funding via two mechanisms: (1) Annual Base Grants (104b) and (2) Nationally Competitive Grants (104g) to the center.

All 50 states annually receive 104b grants to support research, education, and outreach activities to address state water issues. To address state water issues, WRC provides funding through a competitive process (modeled after nationally competitive grant programs from federal agencies) to researchers from all Alabama universities. WRC is responsible for issuing RFP, receiving proposals, convening a review panel to select projects worthy of funding, and managing grants. This includes all activities associated with pre- and post-award management.

The 104g grant program is a nationally competitive grants program facilitated through the AWRRI program and WRC. Researchers from Alabama universities submit proposals to WRC/AWRRI, which are then forwarded to NIWR for review. If a proposal is funded by NIWR, WRC/AWRRI manages all post-award activities associated with the funded project.

The AU WRC/AWRRI consists of interdisciplinary teams of research, teaching, and Extension outreach faculty and staff who address all types of water related issues in Alabama, the Southeast, and around the globe. The research activities are funded through the AL WRRI, the AAES, and a wide variety of extramural sources. The Extension and outreach activities are carried out through the ACES, extramural sources and through three longstanding AU WRC programs, Alabama Water Watch (AWW), 4-H AWW, and Global Water Watch (GWW).

AWW is a statewide program developed by Auburn University and dedicated to promoting community-based watershed stewardship through developing citizen volunteer monitoring of Alabama's streams, rivers, lakes and coastal waters, and has a successful history exceeding twenty years. The AWW Program became part of the AU WRC in 2013. The 4-H AWW Program, included in the AWW Program, is a statewide youth volunteer water quality monitoring program created through a partnership between AWW and Alabama 4-H, the youth development program of ACES. Qualified volunteers and educators lead students in water data collection and watershed stewardship activities that promote environmental literacy and science education.

GWW is a worldwide network of citizen groups developed by Auburn University, promoting community-based, science based watershed stewardship. GWW is committed to spreading environmental literacy, and monitoring of streams, rivers, lakes and coastal waters to achieve improvements in water quality, water policy and public health. TheGWW Program has a successful history of more than twenty years and became part of the AU WRC in 2013.

WRC is also the lead in hosting the annual Alabama Water Resources Conference (AWRC) in Orange Beach, AL. This conference is the main water conference for the state. WRC has been hosting this conference for the last 30 years. WRC staff is engaged in all aspects of hosting this conference.

The AU WRC and AL WRRI are led by the Center's Director, Dr. Puneet Srivastava. Dr. Srivastava has a 50% administrative and 50% research appointment, and manages a rigorous research program in addition to the aforementioned three programs within the AU WRC.

Impact of WRC/AWRRI Research Programs

Dr. Srivastava was invited to attend the US National Academy of Engineering symposium on quantitative methods for determining groundwater depletion in 2016. Only 50 experts from across the nation were invited to attend this invitation-only symposium.

Dr. Srivastava was appointed by the Governor of Alabama, Robert Bentley, to two Focus Area Panels of the Alabama Water Agencies Working Group (AWAWG) to recommend water resources management strategies to use and protect Alabama's water resources.

Apalachicola-Chattahoochee-Flint (ACF) River Basin Drought Early Warning System (DEWS). Our extensive climate/drought research and outreach efforts have allowed us to become a leader in drought/climate research and outreach in the Southeast.

Our high quality research in the water area has allowed us to co-author a water policy paper with a few key state authorities in water area. Bearden, B., P. Srivastava, R. McNider, and A. Ernest. 2016. The Next Frontier in Alabama Water Policy: The Food-Energy-Water Nexus. The WAVE Water Policy Column. The WAVE, 37(2): 17-22.

Impact of Extension, Outreach, and 4-H Programs

AWW conducted 101 training sessions with a total of 870 certifications awarded; about 60% were conducted by or with a citizen trainer. Thirty-nine water chemistry workshops (331 people), 27 bacteriological workshops (292 people), four Exploring Our Living Streams workshops (67 people), 15 recertification sessions (61 people), four trainer refresher workshops (26 people), and 4 trainer internships were completed in 2016 (see www.alabamawaterwatch.org/about-us/reports). Sixty-three groups (313 active monitors) collected and submitted water quality data from all 10 major river basins in AL in 2016. Ten new groups joined AWW in 2016. A total of 2,927 data records was received at the AWW office in 2016. Almost 2,400 people were subscribed to the AWW list-serve and received the AWWareness blog covering AWW watershed stewardship activities and success stories. The AWW website, www.alabamawaterwatch.org, experienced 61,437 page views (over 3,000/month), was viewed by 50 of 50 states, viewed by 112 countries worldwide by 14,240 unique users, average visit of 2.7 minutes, and 60.5% of visits were new visitors.

AU WRC Drought Early Warning Webinars provided more than 300 stakeholders up-to-date drought condition and forecast information on a monthly basis (which shifted to every two weeks at the onset of drought) to aid in drought preparedness, and provided webinar summaries to a wider network of stakeholders throughout the Southeast. A number of emails were received from stakeholders commending our effort and describing how they use the information in making decisions related to their water management.

Global Water Watch (GWW) assists fostering and backstopping community-based, science-based watershed stewardship, in other US states and countries; through the development of long-term citizen volunteer monitoring of surface waters. Citizen-generated data is used to determine the condition and trends of water quality and quantity for the improvement of both public health and watershed health. GWW has certified about 1,300 citizen monitors who have submitted, to an AU-based online database, more than 8,000 water quality and quantity data records from about 500 sites on 200 waterbodies. GWW training sessions were held in Bolivia, Kenya, and Seattle; and intensive training and monitoring activities were conducted in Mexico as part of a large, 5-yr project funded by the World Bank. GWW has spread to half of the 31 states if Mexico as of 2016. GWW is also active in Argentina, Bolivia, Kenya, Mexico, Peru, and the state of Washington. In October of 2016 Dr. P. Srivastava, J. Woods (Ag Communications and Marketing), W. Deutsch and S. RuizCórdova spent six days in Veracruz, Mexico attending meetings and conducting interviews while recording video of GWW activities. This video will be used to intensely promote GWW work and attract funding and potential partners. GWW-Mexico has become the model to follow for citizen science and environmental monitoring, as scores of individuals are now conducting six types of water monitoring.

The 4-H Alabama Water Watch Program (4-H AWW) is the statewide youth water quality monitoring program created through a partnership between Alabama Water Watch and Alabama 4-H, the youth development program of the Alabama Cooperative Extension System (ACES). 4-H AWW increases environmental literacy by building capacity in volunteer trainers and educators to provide youth with an increased awareness and understanding of watershed issues and tools that cultivate the critical thinking skills students need to identify and solve problems related to water quality. In 2016, a new edition of the AWW Exploring Our Living Streams curriculum (which, in addition to stream biomonitoring modules, includes new modules on water chemistry monitoring and data analysis) was developed and printed; 65 educators including teachers, 4-H staff, and volunteers were trained to utilize the AWW Exploring Our Living Streams curriculum during three workshops; more than 1,500 youth were reached through 4-H AWW activities; and 105 youth were certified as 4-H AWW water quality monitors.

4-H AWW activities on Increasing Environmental Literacy and Watershed Stewardship through Youth-Focused Citizen Science, was also supported by a 2-year project funded by the EPA Office of Environmental Education with the goal of building capacity within the 4-H Alabama Water Watch Program (4-H AWW) to provide educators with the training, materials, and support needed to increase environmental literacy for youth (ages 9 18) and engage them in watershed stewardship through water monitoring. In 2016, several major project objectives were accomplished, 1) Development of 4-H AWW Exploring Our Living Streams: An Introduction to Watershed Stewardship, Stream Biomonitoring, and Water Chemistry Monitoring curriculum was completed in May 2016. This curriculum guides educators as they provide students with hands-on citizen science experiences focused on conducting water chemistry analysis and biomonitoring in their local communities. An online Citizen Science Data Simulation (CSDS) was developed to be used alongside or separately from the EOLS curriculum. The AWW CSDS provides interactive activities that teach how to enter data, create simple graphs, and analyze and interpret water data collected by volunteer monitors. The CSDS is published on the AWW website https://web.auburn.edu/aww/csds/. 2) Sixty-five educators were trained to utilize the curriculum during four workshops facilitated in partnership with environmental centers throughout the state. 3) AWW Staff has provided support to participating educators as they implement the curriculum by helping them access monitoring materials, managing the AWW website and database, and assisting educators with student trainings.

Research Program Introduction

Research Program Introduction Research Program Introduction The essential ingredient for determining proper policies and practices is factual information. Often such information must be obtained by means of scientific research. The Alabama Water Resources Institute (AL WRRI) conducts a program that stimulates, sponsors, and provides funding for research, investigation, and experimentation in the fields of water and of resources as they affect water, and encourages the training of scientists in the fields related to water.

Objectives of the AU WRC and AL WRRI are: 1. To plan, conduct and otherwise arrange for competent research that fosters (a) the entry of new research scientists into the water resources fields, (b) the training and education of future water scientists, engineers and technicians, (c) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (d) the dissemination of research results to water managers and the public. 2. To identify major research needs and develop for Alabama and the Southeastern Region short- and long-term research priorities.

3. To encourage research applying to other environmental resources closely associated with water. 4. To maintain close consultation and collaboration with governmental agencies, public groups, and cooperate closely with other colleges and universities in the state that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designed to resolve state and regional water and related land problems.

Integrating Remote Sensing and Biogeochemical Characterizations at High Resolutions to Determine Source and Amount of inorganic and Organic Nutrients Exported From Agricultural Watersheds

Basic Information

Title:	Integrating Remote Sensing and Biogeochemical Characterizations at High Resolutions to Determine Source and Amount of inorganic and Organic Nutrients Exported From Agricultural Watersheds
Project Number:	2016AL175B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	AL007
Research Category:	Not Applicable
Focus Category:	Water Quality, Non Point Pollution, Hydrology
Descriptors:	None
Principal Investigators:	Yuehan Lu, Eben North Broadbent

Publications

There are no publications.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE: Integrating Remote Sensing and Biogeochemical Characterizations at High Resolutions to Determine Source and Amount of Inorganic and Organic Nutrients Exported from Agricultural Watersheds

B. PRIMARY PI(s): Name(s), Title(s) & Academic Rank(s)
Yuehan Lu, Associate Professor, University of Alabama

C. OTHER PI(s): Name(s), Title(s) & Academic Rank(s)
Eben N. Broadbent, Ph.D., Assistant Professor, University of Florida
Angelica Alemyda, Ph.D., Assistant Professor, University of Florida

D. START DATE: March 1, 2016

E. END DATE: February, 2017

F. PROJECT OVERVIEW/SUMMARY:

Agricultural lands are among the most important non-point sources of nutrient pollution impairing water quality in streams and rivers throughout the US. According to the 2012 Alabama Water Quality Assessment Report published by EPA, approximately 842 assessed stream and river miles in the state of Alabama are impaired by nitrogen or phosphorus enrichment. N and P runoff from fertilizers and animal wastes cause eutrophication, where excessive growth of plant and algae leads to changes in water chemistry and biological habitats. Relative to inorganic N and P nutrients, dissolved organic matter (DOM) is less recognized and understood for its importance in controlling water and habitat quality. DOM is a natural organic matter that is a heterogeneous mixture of compounds (e.g., lipid, protein, carbohydrate, lignin), with dissolved organic carbon, nitrogen, and phosphorous (DOC, DON, and DOP) being the primary constituents. In Alabama, agricultural watershed exports of inorganic and organic nutrients remain poorly quantified. Few empirical data have been reported on nutrient loads at watershed scales. To our knowledge, this is the first project 1) assessing inorganic and organic nutrient loading from agricultural watersheds in N. Alabama; 2) concerning concurrent characterizations of watersheds and stream biogeochemistry at multiple spatial and temporal resolutions. Our main results include:1) establishing annual record of inorganic and organic nutrients exported from 15 watersheds along a gradient of agricultural lands in Alabama; and 2) collecting an annual high-temporal resolution multi-platform/multi-sensor record of visual, multi-spectral and LiDAR remote sensing data from MODIS, Landsat, and unmanned aerial vehicles (UAVs), across the four watersheds to map land use and land cover and its phenological variation; and 3) preliminary Integration of watershed data with stream nutrient variability under to understand mechanisms regulating nutrient exports from watersheds of varying land use.

G. PROJECT OBJECTIVE(s): Briefly explain the project objectives.

We proposed to conduct a one-year investigation on inorganic and organic nutrient exports from four streams along a gradient of agricultural lands in northwestern AL,

combining watershed and biogeochemical characterizations at highest possible spatial and temporal resolutions. The overarching goal is to elucidate the role of watershed land use/land cover and hydrology in variation in controlling the variation in dissolved inorganic and organic nutrients in streams. This includes three more specific objectives:
1) Establishing an annual record of the quantity and quality of dissolved nitrogen and organic matter exported from stream watersheds along a gradient of agricultural lands;
2) Identifying non-point sources and evaluating their importance in controlling and predicting nutrient exports from agricultural watersheds;
3) Collecting an annual high-temporal resolution multi-platform/multi-sensor record of visual, multi-spectral and LiDAR remote sensing data from MODIS, Landsat, and unmanned aerial vehicles (UAVs), across the six watersheds to map land use and land cover and its phenological variation;
4) Integrating hydrology and watershed data with stream nutrient data to understand climate and land use drivers on the variability of nutrient export.

H. METHODOLOGIES: Briefly explain the research methodology used.

Main research strategies include: 1) regular sampling and field measurements of selected watersheds for a year; 2) sophisticated biogeochemical analyses of stream water; 3) establishing statistical models predicting stream water nutrient variations using watershed and hydrological parameters.
More specific methods are given in details below:

Study sites—Our study area is within Bear Creek watershed in Northwestern Alabama. The watershed is home to 104 known fish species, higher than any other Tennessee River tributary system in Alabama, and is identified as a Strategic Habitat Unit for freshwater species of concern. In addition to pasture and cropland land use, the watershed has a number of concentrated animal feeding operation.

Sample collection and filtration – In order to minimize the confounding influences of storm events, we collected surface stream water samples at least two days after the most recent precipitation. We estimated storm flows in the study watersheds according to the results from D = 0.827A0.2 (D = time between storm crest and end of overland runoff in days, A = drainage basin area in square kilometers; Fetter 2001). During sampling collection, we measured a suite of in situ environmental parameters including water temperature, dissolved oxygen concentration, conductivity, and pH. We collected stream water samples in duplicate or triplicate and filtered samples using 0.7 μm pore size GF/F glass fiber filters.

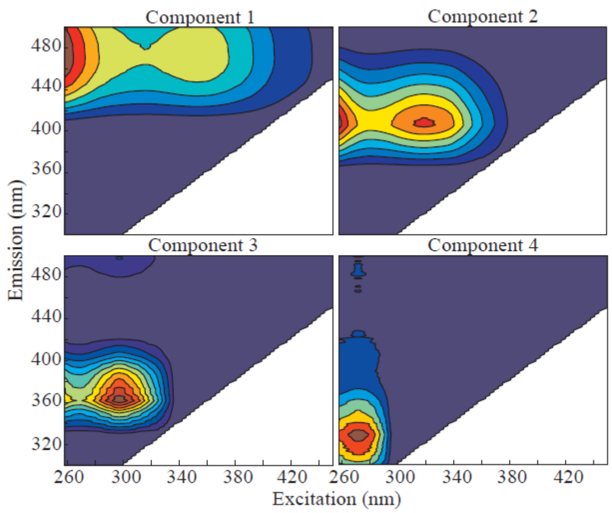
Chemical analysis – Samples were analyzed for inorganic nutrient concentration, DOC (dissolved organic carbon) concentration, DOM (dissolved organic matter) absorption and fluorescence properties, E.coli, as well as cations and stable water isotopes to indicate flow paths.

Watershed analysis – We used MODIS to characterize phenological changes and ecosystem productivity at a spatial resolution of 250x250m, which has the ability to collect bi-weekly or better images during the course of our study. In addition, we characterized broad trends in climatological factors through incorporation of data available from local climate stations, including temperature and relative humidity, precipitation quantity and variability, solar radiation, etc..

I. PRINCIPAL FINDINGS/RESULTS: Explain the results of findings of this research project

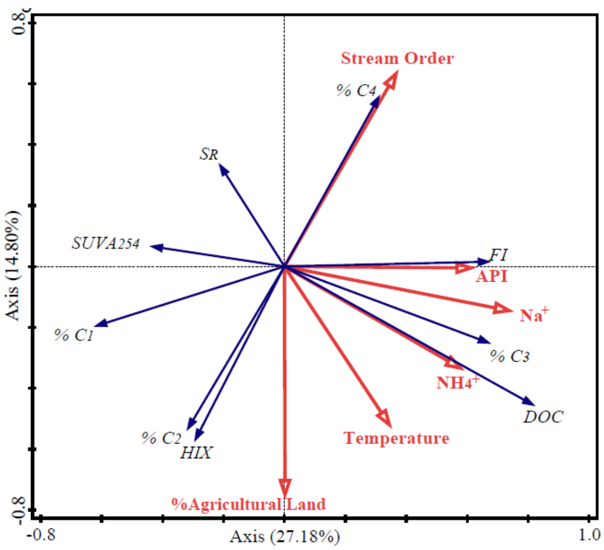
All results are cited from Shang et al., under review.

1) Four types of organic compounds were identified:



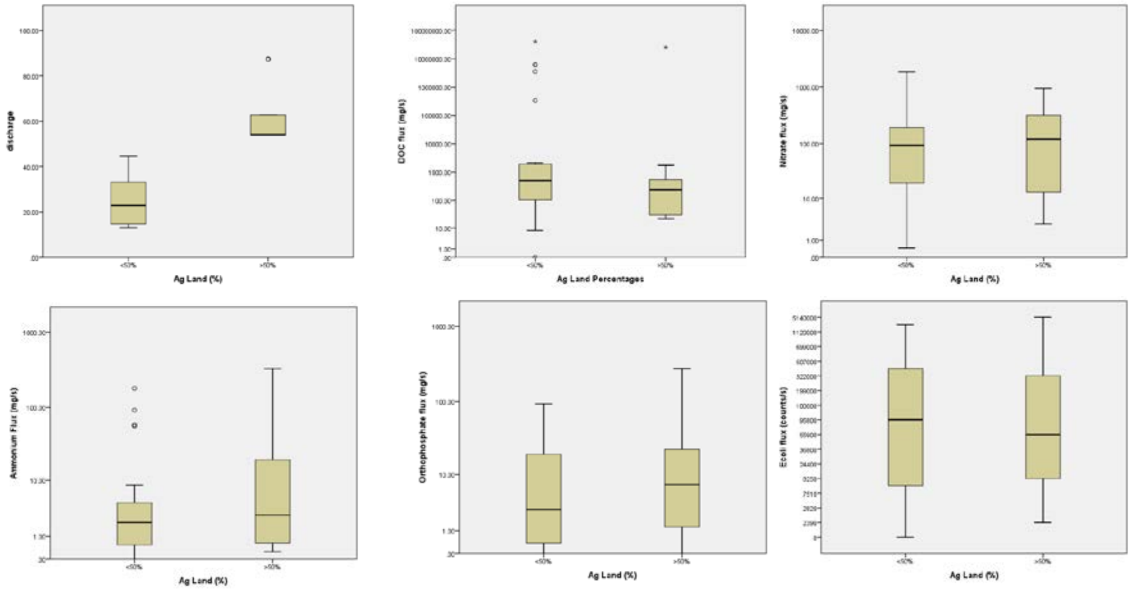
Fluorescence spectra of DOM samples form the Bear Creek watershed. Component 1 and 2 represent terrestrial, humic-like compounds from soils, component 3 represents microbial humic compounds from soils, and component 4 represents protein-like compounds derived from aquatic microbes.

2) Temperature and soil moisture played the first-order control of nutrient export from agricultural watersheds, while land use played the second-order control.



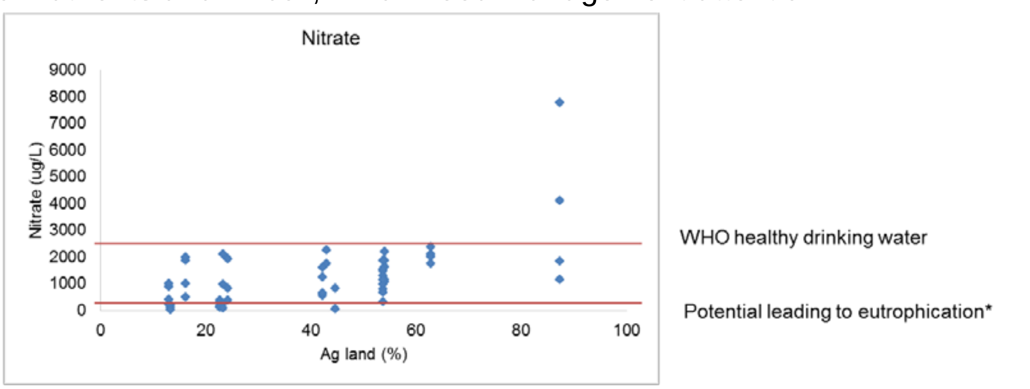
Redundancy analysis of climatic and watershed variables as predictors for DOM in streams in the Bear Creek Watershed. Results show that temperature and soil moisture (indicated by API) are positively influencing the concentrations of DOC and percent contributions of microbial compounds (%C3 and FI). Agricultural land use, however, positively influences percent contributions of soil-derived, humic compounds.

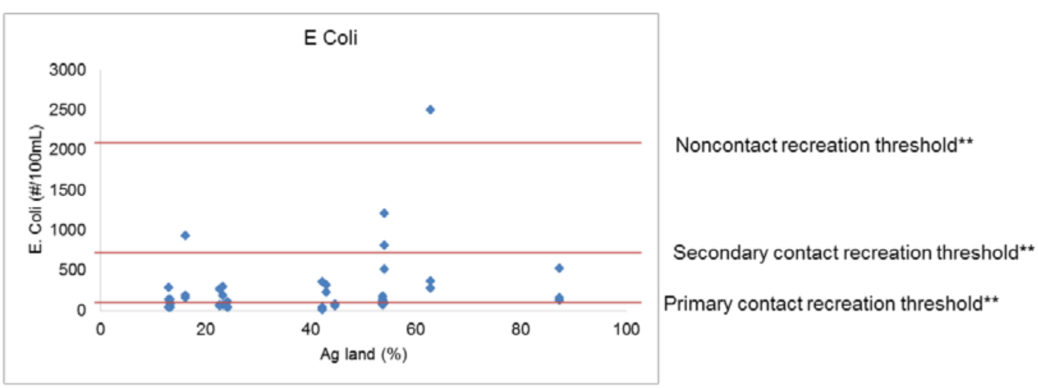
3) Watershed exports of nutrients and E coli (discharge * concentration) did not vary as a function of agricultural land use.



Box plots comparing watersheds with <50% Ag lands vs. >50% Ag lands. Data are based on monthly sampling of 15 watersheds from April to November, 2016. Independent Kruskal-Wallis Test show only discharge is significantly different from two types of watersheds (P<0.005).

4) However, several watersheds were identified consistently exporting high amount of nutrients and E. coli, which need management attention.





*Vollenweider, R.; Kerekes, J. Eutrophication of waters. Monitoring, assessment and control. *Organization for Economic Co-Operation and Development (OECD), Paris* **1982**, *156*

***Bacteria and surface water quality standards http://twri.tamu.edu/docs/education/2012/em114.pdf*

5) Regression models are built to predict stream water nutrients, and the associated results are presented in Shang et al., under review.

J. NOTABLE AWARDS AND ACHIEVEMENTS. List any awards or recognitions for this research

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	1 under review
Book Chapters	
Theses and Dissertations	
Water Resources Institute Reports	
Articles in Conference Proceedings	2
Other Publications	

PROVIDE A CITATION FOR EACH PUBLICATION USING THE FOLLOWING FORMATS:

1. Articles in Refereed Scientific Journals Citation

Author (first author; last name, first name; all others; fist name, last name), Year, Title, Name of Journal, Volume(Number), Page Numbers.

Climatic and Watershed Controls of Dissolved Organic Matter Variation in Streams Across a Gradient of Agricultural Lan Use. Peng, Shang; Yuehan, Lu; Yingxin Du; Rudolf Jaffe; Robert Findlay; Anne Wynn; Aquatic Sciences, Under Review

2. Book Chapter Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of chapter, "in" Name(s) of Editor "ed.", Title of Book, City, State, Publisher, Page Numbers.

3. Dissertations Citation

Author (last name, first name), Year, Title, "MS (Ph.D.) Dissertation," Department, College, University, City, State, Number of Pages.

4. Water Resources Research Institute Reports Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, Name of WRRI, University, City, State, Number of Pages.

5. Conference Proceedings Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of Presentation, "in" Title of Proceedings, Publisher, City, State, Page Numbers.

1) Lu, Y., Cohen, S., Wilson, H., Shang, P. (2016). Does Human Land Use Alter the Amount and Quality of Dissolved Organic Matter in Lotic Ecosystems? In Goldshcmidt Abstract book: **https://goldschmidt.info//abstracts/abstractView?id=2016002995**, Yokohama, Japan
2) Lu, Y. (2016). Dissolved organic matter in lotic ecosystems. In Abstract Book for 1st Shenzhen Forum on Ocean Sciences for Young Scholars, Shenzhen, China
3) Shang, P., Lu, Y., Du Y, Jaffé, R., Findlay, R., Wynne, A. (2016). Climatic and Watershed Controls of Dissolved Organic Matter (DOM) Variation in Streams across a Gradient of Agricultural Land Use. In Program of Alabama Water Research Conference, http://aaes.auburn.edu/wrc/wp-content/uploads/sites/108/2016/09/Proceedings.pdf

6. Other Publications Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, other information sufficient to locate publications, Page Numbers (if in publication) or Number of Pages (if monograph).

L. PRESENTATIONS MADE:

Presenter(s) (last name, first name; all others presentation authors: first name, last name), Year, Title, other information sufficient to identify the venue in which the presentation was made.

1) Lu, Yuehan, March 31, 2017, Mississippi State University Department of Geological Sciences Seminar, “Dissolved Organic Matter in Lotic Ecosystems as an Integrator of Watershed and Hydrological Processes”. Invited Talk
2) Lu, Yuehan, August 06, 2016, Nanjing University, China, Department of Geological Sciences Seminar, ““Dissolved Organic Matter in Lotic Ecosystems as an Integrator of Watershed and Hydrological Processes”. Invited Talk
3) Lu, Yuehan, August 08, 2016,Tongji University, China, School of Earth and Ocean Science Seminar, “Dissolved Organic Matter in Lotic Ecosystems as an Integrator of Watershed and Hydrological Processes”. Invited Talk
4) Lu, Yuehan, October 13, 2016, Wheeler National Wildlife Refuge Visitors Center, AL “Bear Creek Watershed Nutrients Exports”. Invited Talk

5) Lu, Yuehan, November 26, 2016, The 1st Shenzhen Forum on Ocean Sciences for Young Scholars, Shenzhen, China, “Dissolved Organic Matter in Lotic Ecosystems”. Invited Meeting Presentation
6) Shang, Peng, et al, September 07-September 09, 2016 Alabama Water Resource Conference “Climatic and Watershed Controls of Dissolved Organic Matter Variation in Streams Across a Gradient of Agricultural Lan Use”. Oral presentation
7) Lu, Yuehan, June 26-July 01, 2016, Goldschmidt Geochemistry Society Meeting, Yokohoma, Japan “Dissolved organic matter in impacted streams and rivers”. Oral Presentation.
8) Chen, Shuo, et al., March 03, 2017, University of Alabama, WiSE meeting, “Effects of Agricultural Land Use on the Source and Composition of Dissolved Organic Matter in Streams”. Poster Presentation.

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	0
Masters	0
Ph.D.	1
Post Doc	0

Number of Theses and Dissertations Resulting from Student Support:	
Master’s Theses	0
Ph.D. Dissertations	1 in progress*

*the main findings from this project make up the key results of one chapter of a Ph.D. dissertation by Shang (expected to graduate in 2018)

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
	Biological Sciences
	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport

	Social Sciences
X	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with “X” in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
X	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
X	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
X	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW

	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
X	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: (Enter keywords of your choice, descriptive of the work)

Land-Water Interactions, Landscape Management, Organic Compounds, Nitrogen, Remote Sensing, Geochemistry, Ecosystems, Water Quality Monitoring

Identification of Stream Bed Sediment Sources Using Sediment Fingerprinting

Basic Information

Title:	Identification of Stream Bed Sediment Sources Using Sediment Fingerprinting
Project Number:	2016AL176B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	AL003
Research Category:	Not Applicable
Focus Category:	Sediments, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Jasmeet Lamba

Publications

There are no publications.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE: Identification of Stream Bed Sediment Sources Using Sediment Fingerprinting

B. PRIMARY PI(s): Jasmeet Lamba, Ph.D., Assistant Professor, Auburn University

C. OTHER PI(s): Ming-Kuo Lee, Professor, Auburn University; Myra A. Crawford, Cahaba Riverkeeper, Birmingham, AL

D. START DATE: March, 1st 2016

E. END DATE: February 28th 2017

F. PROJECT OVERVIEW/SUMMARY: Excessive delivery of sediment to surface waters results in increased turbidity, reduced light penetration and transport of sediment-bound nutrients, such as phosphorus (P) to surface waters. Implementation of best management practices (BMPs) helps to reduce excessive delivery of sediment and sediment-bound contaminants to streams and thereby improve water quality. To effectively target and implement appropriate BMPs, the provenance of sediment must be known. Targeted implementation of BMPs would enable effective use of federal and state funds to alleviate pollution issues. Sediment fingerprinting techniques have been successfully used to identify sources of in-stream sediment. These techniques involve identification of potential sediment sources and allocating the amount of sediment contributed by each source through the use of natural tracers and a combination of field data collection, laboratory analysis, and statistical modeling techniques. In this project, sediment fingerprinting technique was used to identify the sources of in-stream sediments in Moore's Mill Creek watershed located in Auburn, Alabama. Potential sources of in-stream sediment considered in this study were eroding stream banks, construction sites and woodlands. Stream bed sediment samples were collected at four different locations within the watershed to identify sources of in-stream sediment at subwatershed level. Additionally, Soil and Water Assessment Tool (SWAT) was used to prioritize the subwatersheds based on sediment yield.

G. PROJECT OBJECTIVE(s):

1. Identify sources of streambed sediment using sediment fingerprinting.
2. Apportion the relative contribution of different sources to streambed sediment at different depth intervals as a function of sediment particle size.

H. METHODOLOGIES: This study was conducted in the Moore's Mill Creek watershed (46 mi^2) located in Auburn AL (Fig. 1). The dominant land uses in this watershed are urban (23%) and woodlands (48%). The potential sources of sediment considered in this study were: (a) based on land use type: woodland and construction sites, and (b) eroding stream banks. Five surface soil samples (top 2.5 cm, the layer susceptible to detachment and mobilization by surface runoff) were collected from each site and composited for analysis. Woodland and construction site samples were collected from 20 different sites (woodland (n = 10) and construction (n =10)). Stream bank cores (5 cm deep) were collected from 10 different sites located within the watershed. At each site, three cores were collected from eroding banks and were composited for analysis. Stream bed sediment cores (top 20 cm) were collected from four sites using a 5 cm diameter acrylic tube and a trowel. At each site, streambed cores were collected from 3-5 representative locations and composited for analysis. Sampling points for stream bed sediment samples (i.e., mid channel or near banks) were based on where the sediment deposits were located. Each core of stream bed sediment collected was sectioned into the following depth intervals: 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm. Samples sectioned into the same depth interval at each site were composited for analysis. The source and streambed sediment samples collected were oven-dried at 60^{o} C, disaggregated using a pestle and mortar, and dried sieved into three particle size fractions, namely, <63 µm, 63-125 µm, 125-212 µm. After dividing the samples into three particle size fractions, the samples are currently being analyzed for geochemical tracers using ICP-MS microwave assisted acid digestion.

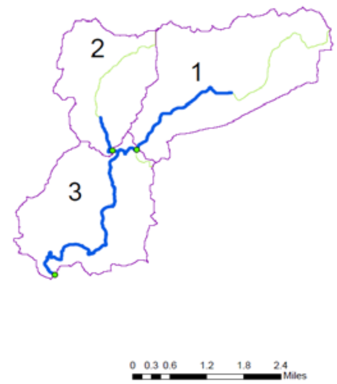


Figure 1 Moore's Mill Creek Watershed.

To determine the erosion rates of the stream banks, erosion-pins were installed at four different sites within this watershed. Three rebars were inserted along the profile of the bank from top to bottom and the length of the rebar exposed from the bank was measured on a monthly basis. The positive values (increase in exposure of the rebar) indicated net erosion

To prioritize reaches with high sediment deposition within this watershed, mass of sediments deposited on stream beds per unit reach length was estimated. The depth of sediments deposited was calculated with a meter stick along 3 transects which ran perpendicular to the direction of flow. The average thickness of sediment deposited for each transect was calculated and then was averaged for the three transects. The average thickness of sediment deposited was multiplied with average channel width and reach length to obtain sediment volume. This volume of sediment was multiplied with the bulk density of sediment to estimate mass of sediment deposited within each reach.

Additionally, Soil and Water Assessment Tool (SWAT) model was used to quantify sediment loading at the subwatershed level. SWAT model was setup for this watershed to prioritize the subwatersheds, which contribute high amounts of sediments into the stream. SWAT model was calibrated and validated for the total stream flow at the watershed outlet. For total streamflow calibration and validation, measured streamflow data by the USGS at the watershed outlet was used. For sediment data, sediment calibration parameters from nearby watershed were used, since no observed data for sediment exists for this watershed. The information obtained from the SWAT model will be used in conjunction with the sediment fingerprinting to identify the dominant sediment sources.

I. PRINCIPAL FINDINGS/RESULTS: The particle size analysis of the stream bed sediment indicates that eroded sediment is dominated by sand particles followed by silt and clay particles. Since the sand sized particles are susceptible to deposition, reaches in this watershed are dominated by sediment deposited on the stream bed. The mass of sediment deposited per feet within the reaches ranged from 768 kg to 1513 kg. Deposition of significant quantities of sediment in the reaches can contribute sediment legacy effect.

Stream bank erosion is prevalent in reaches within this watershed. Average monthly stream bank erosion rates measured using rebars ranged from 0.1 to 0.27 inches per month, indicating variability in bank erosion rates among different sites within the watershed. Different factors (e.g., stream bank characteristics, stream flow volume) can contribute to variability in stream bank erosion rates. The SWAT model was successfully calibrated and validated at a monthly-time step for total stream flow against the measured streamflow data at the watershed outlet. Model evaluation statistics used in this study included Nash-Sutcliffe efficiency (NSE) and coefficient of determination (R^2) (Table 1).

Table 1 The values of NSE and R^2 for calibration and validation of the SWAT model at a monthly time-step.

Variable	Calibration		Validation	
	NSE	R^2	NSE	R^2
Streamflow	0.57	0.84	0.43	0.85

The average annual sediment yield estimated using SWAT model for subbasins 1, 2 and 3 (Fig. 1) was 3.4, 2.2 and 3.6 tons per hectare, respectively. The sediment load at the outlet of the Moore's Mill Creek watershed ranged from 6.6 to 990 tons at a monthly time step. Preliminary results show that both construction sites and stream banks are important sources of sediment in this watershed. The results obtained from the sediment fingerprinting will help to determine relative contribution of each source at a subwatershed level and therefore help in targeting management practices at areas contributing disproportionately high amount of sediment to streams.

J. NOTABLE AWARDS AND ACHIEVEMENTS.

1. Third prize in the research poster presentation at Alabama Water Resources Conference Orange Beach, Alabama. 2016.
2. Certificate of Research Achievement from Biosystems Engineering Department, Auburn University, Auburn, Alabama. 2017.

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	1 (in progress)
Book Chapters	
Theses and Dissertations	1 (in progress)
Water Resources Institute Reports	
Articles in Conference Proceedings	
Other Publications	

1. Articles in Refereed Scientific Journals Citation

Malhotra, Kritika; Jasmeet Lamba; Puneet Srivastava, 2017, Identifying Sources of In-Stream Sediment Using Inorganic Tracers (to be submitted to Journal of Hydrologic Engineering)

2. Dissertations Citation

Malhotra, Kritika, 2017. Using sediment fingerprinting technique and SWAT modeling to improve our knowledge on sediment transport dynamics, "M.S. Thesis," Biosystems Engineering Department, Auburn University, Auburn, AL (in progress)

L. PRESENTATIONS MADE:

1. Malhotra, Kritika; Jasmeet Lamba; Puneet Srivastava, 2017, Identifying Sources of In-Stream Sediment Using Inorganic Tracers, Alabama Stormwater Forum, Auburn, Alabama.

2. Malhotra, Kritika; Jasmeet Lamba; Puneet Srivastava, 2017, Tracing In-Stream Sediment Sources in an Urban Watershed using Sediment Fingerprinting Technique, American Society of Agricultural and Biological Engineers Conference AL-Section, Auburn, Alabama.

3. Malhotra, Kritika; Jasmeet Lamba; Puneet Srivastava, 2016, Sediment fingerprinting to Identify Sources of In-Stream Sediments in an Urban Watershed, Alabama Water Resource Conference, Orange Beach, Alabama.
4. Malhotra, Kritika; Jasmeet Lamba; Puneet Srivastava, 2016, Sediment fingerprinting to Identify Sources of In-Stream Sediments in an Urban Watershed, Graduate Research Showcase, Auburn University, Auburn, Alabama.

M. STUDENTS SUPPORTED

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	1
Masters	1
Ph.D.	
Post Doc	

Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	1
Ph.D. Dissertations	

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
	Biological Sciences
	Climate and Hydrological Processes
X	Engineering
	Ground Water Flow and Transport
	Social Sciences
X	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with “X” in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
x	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
	MANAGEMENT & PLANNING	M&P
	METHODS	MET
X	MODELS	MOD
	NITRATE CONTAMINATION	NC
X	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC

X	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
x	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
X	WATER QUALITY	WQL
x	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: Sediment Fingerprinting, Stream bank erosion, In-Stream Sediments

Onsite Wastewater Management in Hale and Wilcox Counties: Failing Septic Systems, Direct Discharge by "Straight Pipes" and Microbial Source Tracking

Basic Information

Title:	Onsite Wastewater Management in Hale and Wilcox Counties: Failing Septic Systems, Direct Discharge by "Straight Pipes" and Microbial Source Tracking
Project Number:	2016AL177B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	AL007
Research Category:	Not Applicable
Focus Category:	Non Point Pollution, Water Quality, Wastewater
Descriptors:	None
Principal Investigators:	Mark Elliott, Kevin White

Publications

There are no publications.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE: Onsite Wastewater Management in Hale and Wilcox Counties: Failing Septic Systems, Direct Discharge by “Straight Pipes” and Microbial Source Tracking

B. PRIMARY PI(s): Name(s), Title(s) & Academic Rank(s)
Mark Elliott, PhD, Assistant Professor, University of Alabama

C. OTHER PI(s): Name(s), Title(s) & Academic Rank(s)
Kevin White, PhD, Professor, University of South Alabama, Mobile
Non-academic PIs:
Parrish Pugh, ADPH, Montgomery
Chandra Lynn Jones and Robert Jones, Down to Earth, Inc., Camden, AL

D. START DATE: March 1, 2016

E. END DATE: February 28, 2017

F. PROJECT OVERVIEW/SUMMARY:

In the Black Belt region of Alabama (Figure 1), low-permeability soils and other factors, including rural poverty, make onsite wastewater management challenging. Black Belt soil and geology make over half of the area unsuitable for conventional septic systems (He et al., 2011). In addition to failing septic systems, many in the rural Black Belt directly discharge raw sewage from the home, usually to a nearby wooded area or ditch through a so-called “straight pipe” (Figure 2). The prevalence of straight pipes and failing septic systems in rural areas with impermeable soil is well-known by health department workers and other stakeholders. However, while the problem has been acknowledged by EPA (EPA Region 4, 2002) and others, almost no data are available on the magnitude of these problems. While straight pipes are clearly illegal, enforcement is inconsistent in many areas. The major challenge preventing substantive government action and funding of this issue is that the scope, volume and impacts of these sewage discharges are largely unknown.

Fig 1: Alabama Black Belt Counties (Source: UA Center for Economic & Business Research)

The federal funding on this grant enabled us to characterize the scope of straight pipe discharges in Black Belt counties for the first time. Down to Earth, Inc. (of Camden, AL) performed site inspections of 790 properties spread throughout Hale and Wilcox counties. In addition to the federal funding, matching non-federal funding for this project has enabled broad characterization of water quality parameters that yield insight into the impacts of straight pipe discharges on surface water quality. The data from these site inspections enabled us to make conservative estimates of (1) the number of households discharging raw sewage in each

Fig 2: A typical straight pipe discharge (EPA Region 4, 2002).

county and (2) the volume of raw sewage discharged and the number of key infectious pathogens discharged to the environment per day in each county.

In Wilcox County, a staggering 60% of households in our sample had a straight pipe discharge that was visible upon inspection. Only 7% of our sample had a permitted onsite wastewater system; 33% of properties had an unpermitted system with unknown discharge (either above or below ground). Based on 60% straight pipe, we estimate that nearly 550,000 gallons of raw sewage is discharged onto the ground per day in Wilcox County. Using published averages of pathogen concentrations in raw sewage, we estimate the following daily discharge of infectious pathogens in Wilcox County alone: 10 Billion enteric viruses, 16 Billion *Giardia* cysts and 3 Billion *Cryptosporidium* oocysts. While these numbers may be hard to digest, this is the equivalent of about 10,000 55-gallon drums of raw sewage being emptied onto the ground each and every day in the Alabama River Basin in Wilcox County alone. Additional data from the project are reported under Principal Findings/Results.

The scope of raw sewage discharge in the Black Belt is both previously unknown and shocking for the United States in the 21st-century. We presented preliminary findings in Fall 2016 at two conferences and received strong interest from EPA headquarters and Region 4. The EPA Office of Wastewater extended an invitation for us to present a 90-minute webinar as part of the EPA Office of Decentralized Wastewater webinar series. Dr. Elliott presented the webinar on March 28th; it had the highest attendance in the history of the webinar series (2010-present). We are in regular contact with the EPA Office of Decentralized Wastewater and they are exploring possibilities for funding solutions through three specific EPA and USDA mechanisms. We believe that this project will lead to the first major effort to address the challenges of onsite wastewater management in the rural Black Belt of Alabama.

G. PROJECT OBJECTIVES:

The project objectives were to physically survey a representative random sample of unsewered households in Hale and Wilcox counties and to conduct water sampling and analysis. The goal of these activities was to produce clear quantitative evidence that onsite wastewater management in these counties is a major source of contamination and, specifically, that straight pipes (surface discharge of untreated household wastewater) are common in these areas.

H. METHODOLOGIES:

Site inspections: Site inspections were conducted by Down to Earth, Inc., a subcontractor with experience conducting onsite wastewater inspections. A representative sample of approximately one-tenth of unsewered households throughout each county was surveyed. The survey received approval by the Human Subjects Research Institutional Review Board (IRB) at UA (IRB #16-OR-241).

The site inspection procedure was initiated by Down to Earth employees and co-PIs Robert and Lynn Jones knocking on doors and asking if adult residents are interested in participating in the study. If so, we provided the relevant information and ask for informed consent. If informed consent was granted, we administered a short (5 question, <5 minute) questionnaire and asked for permission to look at the wastewater system. If granted permission, we recorded observations. It is essential that we maintain the confidentiality of individual homeowners with unpermitted onsite wastewater management, particularly straight pipes. Therefore, all mapped results of site inspections are presented to prevent identification of individual households.

Water sampling and analysis: Water sampling was conducted using best practices for surface water sampling from USGS (Wilde et al., 1998). Shortly after receiving this grant, we received a small companion grant from the UA Center for Freshwater Studies (PI – Elliott, co-PI Yuehan Lu in Geology) that enabled us to leverage water sampling activities and analyze more parameters. Analysis of many biological and geochemical parameters was completed. Principle component analysis (PCA) was used to identify a number of promising parameters for inexpensive and robust detection of wastewater contamination.

Water samples have been collected and analyzed regularly throughout the project period for parameters including the following: *E. coli*, total coliform bacteria, conductivity, pH, turbidity, cations (most notably Ca, Mg, K, Na), anions (most notably chloride and sulfate), and nutrients (most notably ammonia, nitrate, nitrite and orthophosphate). We also conducted extensive dissolved organic matter (DOM) characterization parameters including total organic carbon-total nitrogen and composition information of DOM from EEM-PARAFAC (excitation emission matrix-parallel factor analysis) that yield a suite of organic proxies including SUVA for aromaticity, S_R for molecular weight, biological indices, freshness indices, humification indices, and percentage contributions of different fluorescence components etc. (Yang et al., 2015, Lu et al., 2013); we also look for the optical brighteners used in detergent as described below.

Fluorescence methods for DOM analysis are based on published methods widely accepted by the scientific community (e.g., McKnight et al. 2001; Lu et al., 2013, 2014, 2015; Jaffe et al., 2014). At least duplicate samples were analyzed for each parameter. DOC concentration was analyzed using a Shimadzu TOC-V total organic carbon analyzer, with calibration curves constructed daily using potassium hydrogen phthalate solutions. Milli-Q water is measured regularly to assess instrumental baseline, and an external control sample used to confirm accuracy. The fluorescence data were acquired using a Horiba Fluoromax fluorescence spectrometer operated at the signal ratio mode (S/R) to compensate for the xenon lamp variation as a function of wavelength. Samples were scanned at excitation wavelengths from 240 nm to 621 nm at 3 nm intervals, and emission wavelengths collected from 213 nm to 621 nm at 2 nm intervals. The data were corrected for inner-filter effect, instrument-specific responses, and blanks. Data are normalized to the area under Raman curve of Milli-Q water at the excitation wavelength of 350 nm. Resulting excitation and emission matrices were processed for parallel factor analysis (PARAFAC) in MATLAB using the DOMFluor toolbox (Stedmon and Bro 2008; http://www.models.life.ku.dk/), and the final model validated by a split-half analysis.

Analysis of human-specific genes using polymerase chain reaction (PCR) assays was initiated but is still in progress. We have filtered, frozen samples that are within the acceptable period for frozen storage and will be analyzed once the assay is working. We recently changed our approach from quantitative PCR (qPCR) to conventional PCR and are collaborating with a colleague in Chemical Engineering to establish the assay. Despite the challenges, we have established a preliminary approach to inexpensive and feasible monitoring for rural wastewater contamination and have a proposed plan to advance this approach.

I. PRINCIPAL FINDINGS/RESULTS:

Site Inspection Results:

A brief summary of the preliminary results is reported in Table 1. The state of wastewater management for unsewered homes is frankly shocking in Wilcox County: 60% of unsewered homes that were inspected had a visible straight pipe discharge and 33% had an unknown, but unpermitted system. An example of mapped results is included in Figure 3 (the geographic area is not specified to maintain anonymity).

Table 1: Preliminary data from site inspections of onsite wastewater systems in Hale and Wilcox Counties (collected fall 2016).

County	Systems Permitted by the Health Department	Status of Unpermitted Systems	% of homes surveyed
Wilcox (n=289)	Permitted systems		7%
	Unpermitted systems		93%
		Visible Straight Pipe	60%
		Unknown unpermitted system [1]	33%
Hale (n=411)	Permitted systems		35%
	Unpermitted systems		65%
		Visible Straight Pipe	6%
		Unknown unpermitted system [1]	59%

[1] "Unknown unpermitted system" could be either some form of in-ground disposal or a straight pipe that is buried/not visible.

In Hale County, 35% of unsewered homes had permitted systems and a relatedly small percentage (6%) had confirmed straight pipes. However, there are two key distinctions needed to interpret these data: (1) only the southern portion of Hale County is dominated by impermeable clay whereas these clays cover nearly all of Wilcox County and (2) one municipality in the north of Hale Co. (Moundville) requires a permitted wastewater solution for property to exchange hands. In Moundville, 96% of homes in our sample had permitted systems; in the southern, clayey soils of Hale County (near the town of Newbern), nearly 50% of homes in our sample had a visible straight pipe and none had a permitted system. Therefore, the status of onsite wastewater in this region depends strongly on permitting requirements by local municipalities. However, there are many areas with impermeable soil where the lack of enforced regulations is almost certainly a function of the infeasibility of affordable onsite wastewater solutions. Understanding the relationship between these variables will be key for our future modeling efforts.

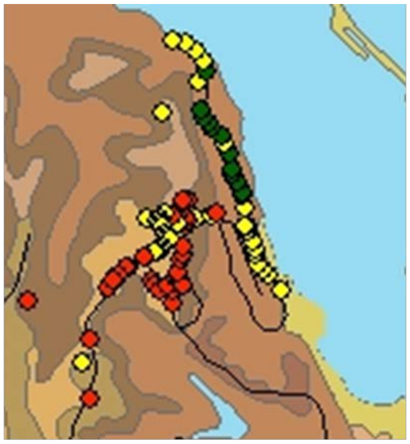


Fig 3: Example of site survey results for one small area in our survey. Green are permitted systems; Yellow are unpermitted with unknown wastewater discharge; Red are straight pipes. The geographic area is not identified to maintain anonymity of residents.

What about the health impacts?: If raw sewage is, in fact, being discharged near homes and backing up into yards in large swathes of the rural American South (Figure 4), we would expect to see higher proportions of infectious disease. However, our medical community has largely moved on from monitoring for the parasitic diseases that were widespread in the US through the early-20th century. Additionally, access to primary healthcare among the rural poor in Alabama is abysmal (e.g., Hale County has two licensed primary care physicians for 15,000 residents and Wilcox County has one for over 10,000 residents). The most recent survey of soil-transmitted helminthiasis in Alabama was a University of Alabama at Birmingham master's thesis conducted in Wilcox County in 1993; it revealed that up to 33% of children under-10 tested positive for one or more helminths (Badham, 1993). Recent, unpublished data from Lowndes County collected by researchers from Baylor College of Medicine reportedly indicate that over 35% of adults with poor sanitation were infected with hookworm (Walton, 2015). Follow-ups to confirm these findings are planned by Georgia Tech faculty member Joe Brown later in 2017.

Fig 4: A child's ball and a pet dog in puddles of sewage from failing septic systems in Lowndes County, AL (ACRE, 2015).

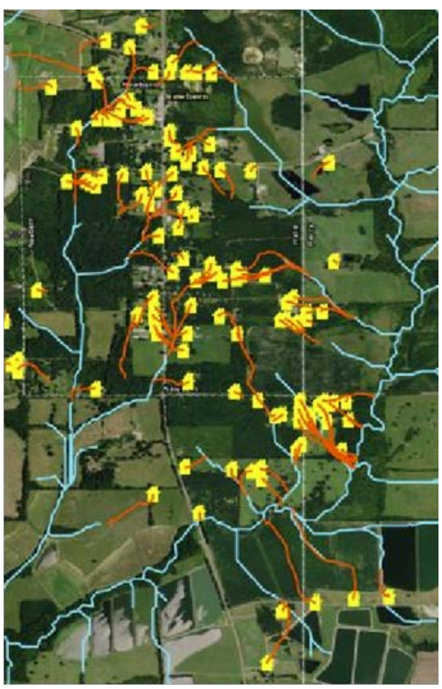


Fig 5: Flow-routing map for part of area around Newbern. Yellow are homes and orange are surface flow routes from homes to streams.

Water Sampling Results:

An extended drought in fall 2016 provided an unexpected opportunity for multiple sampling trips before and then immediately following the first rain in over two months. Newbern, Alabama, a small town with a conservative estimate of 50% straight pipes and very impermeable clay soil, provided an ideal setting to sample runoff containing untreated wastewater. GIS-based flow-routing helped us to identify accessible sampling sites Upstream, adjacent to Newbern (Midstream) and Downstream of the town on Big Prairie Creek (Figure 5). Flow-routing revealed where runoff from Newbern enters Big Prairie Creek; therefore, our sample design enabled us to determine the impact of these straight pipe discharges on creek water quality.

Principal component analysis (PCA) was used to identify analyte signatures associated with sewage contamination. The PCA (varimax rotation) identified three primary components (Eigenvalue >1), accounting for 40.4%, 19.0% and 8.7% of total variance respectively. The wastewater end members are well separated from stream water and post-drought (first

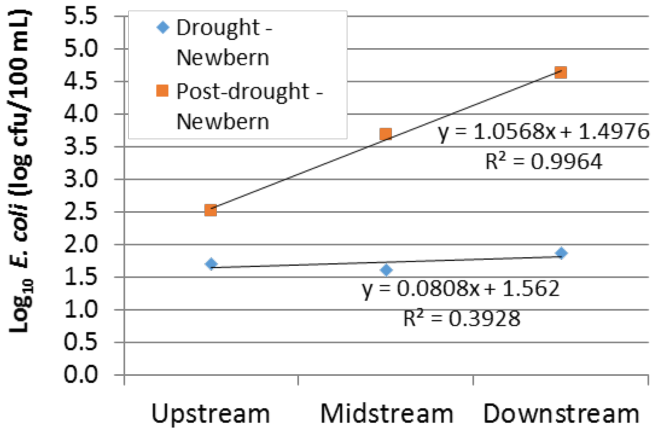


Fig 6: Median $\log_{10}$ *E. coli* per 100 mL at sampling sites Upstream, adjacent (Midstream) and Downstream of Newbern, Alabama.

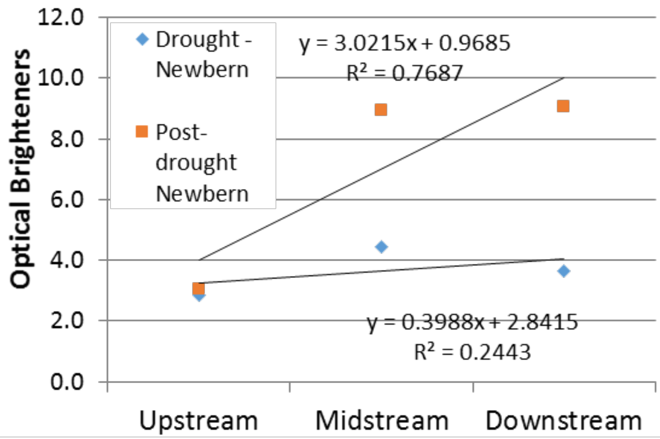


Fig 7: Median optical brightener signal at sampling sites Upstream, adjacent (Midstream) and Downstream of Newbern, Alabama.

flush) water samples by PC1, which is dominated by soluble reactive phosphorous (SPR), dissolved organic carbon (DOC), *E. coli*, Ammonium-N, protein fluorescence, and optical brighteners. All these indicators demonstrate that wastewater has a characteristic nutrient &microbe-rich signal that can be used to trace water sources in natural waterways, which is well synthesized by PC1. The post-drought samples had a higher PC1 score than stream water samples, indicating precipitation mobilizes sewage related chemicals into nearby streams. Using base-flow stream water and wastewater as end members, we estimated that post-drought stream water contains 6.7% of wastewater. PC2 and PC3 are associated more with hydrological flow paths and hence not discussed in detail here. Figure 6 illustrates how during the drought under baseflow conditions, sampling sites Upstream, adjacent (Midstream) and Downstream of Newbern show no change in *E. coli* concentration. In contrast, during the first rain storm following the drought, median *E. coli* concentrations increased by less than one log unit upstream but by nearly 3 $\log_{10}$ (1000x) downstream. Figure 7 shows the pattern seen for optical brighteners. PCA results verified these observations by showing increasing PC1 scores from upstream to downstream site (Figure 8).

Optical brighteners found in detergent (and whiteners in toilet paper) yield a strong absorbance-emission signal that is simple and inexpensive to measure with a handheld or laboratory fluorometer (Hagedorn and Weisberg, 2011). While many investigators have concluded that these compounds have great potential as a screening step for wastewater contamination in natural waters (Hagedorn and Weisberg, 2011; Cao et al., 2009; Tavares et al., 2008), one study in California found that they were not sensitive enough to detect even reasonably high levels of wastewater contamination (Griffith et al., 2009). These compounds show great promise in our preliminary data to act as an indicator of human fecal contamination from onsite wastewater

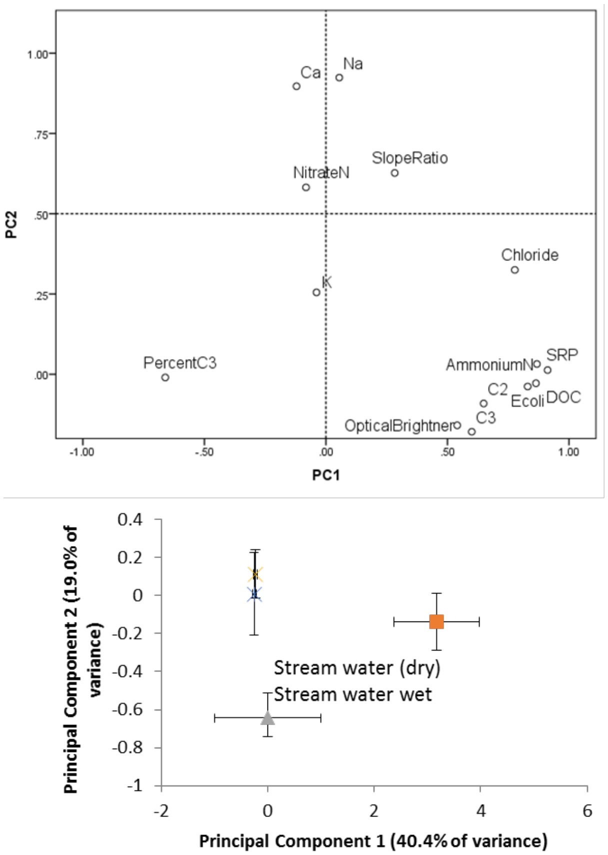


Fig 8: Principal component analysis of geochemical and microbiological indicators of stream water and wastewater samples. The upper panel shows the loading plot of different indicators with the wastewater associated analytes grouping in the bottom right (note highly-correlated indicators are removed to avoid collinearity), and the lower panel shows loadings scores for different types of water samples.

discharges in rural Alabama streams. Data at our pristine (no human influence) control site at Mayfield Creek showed an average optical brightener signal of 0.83 during the Drought and 2.83 just after the Drought. In rural areas in particular, optical brighteners are promising as supplement to fecal indicator bacteria, possibly enabling differentiation of wastewater from animal fecal contamination (Tavarese et al., 2008).

The EEM-PARAFAC model identities three fluorescence components, terrestrial, humic-like compounds derived from soils, microbial humic like compounds, and protein-like compounds. The fluorescence spectra clearly show that wastewater samples (Fig. 9a) have higher proportions of microbially-produced, protein-like compounds than a typical stream water samples with no input of wastewater (Fig. 9b). From the upstream site of Newborn with no known input of wastewater to the downstream site receiving inputs from a large number of straight pipe discharges, the dominant fluorescence region shifts from indicating humic, soil-derived compounds to indicating microbially-derived compounds. The present fluorescence model is based on 112 samples. Because of the distinctive fluorescence character between wastewater samples vs. pristine streams water samples (Fig. 9a vs. 9b), we expect to identify and quantify a fingerprinting fluorescence component with a larger sample size.

In October 2016, Dr. Elliott presented the preliminary project findings at the UNC Water and Health Conference. Based on these project findings, in February he was invited to present a webinar in the EPA Decentralized Wastewater webinar series. The webinar was presented on March 28th and has led to substantial interest at EPA Region 4 and EPA Headquarters to address the problem. He has also received inquiries from numerous state and territorial agencies (including Mississippi, Hawaii, Puerto Rico and Louisiana) interested in sharing ideas and collaborating on similar investigations.

In April 2017, Dr. Elliott began discussions with EPA on potential ways to leverage funding (through three specific USDA and EPA mechanisms) to pilot wastewater treatment solutions in the region; partners at EPA are currently exploring the options. Given the pace of these developments and the interest at federal and state agencies it is realistic, even likely, that these activities will lead to implemented pilot solutions by the end of 2018.

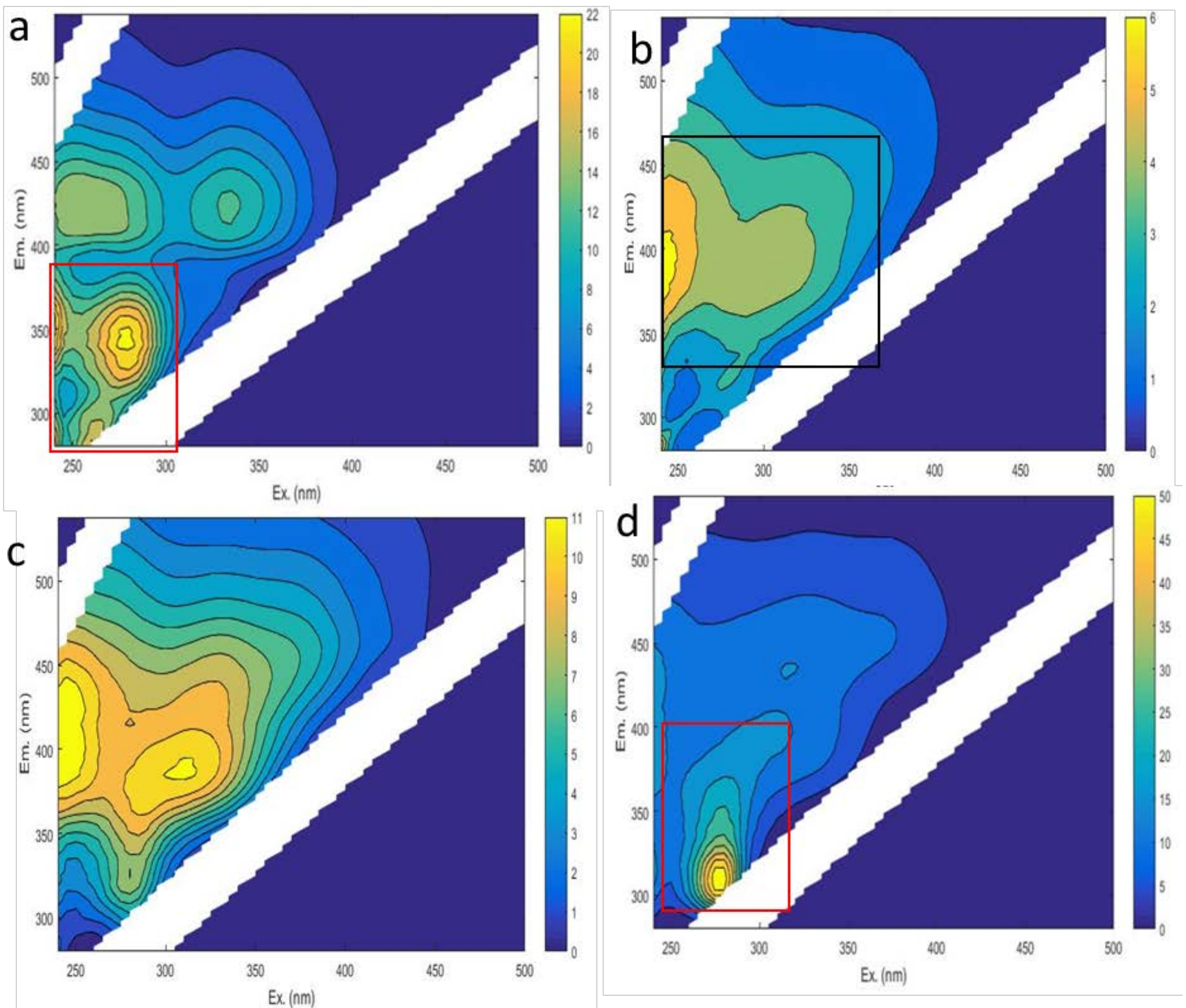


Fig 9: (a) typical wastewater DOM fluorescence results for project samples. Intensity is in Raman units. The red rectangle outlines the fluorescence region indicative of microbially-produced compounds. DOM fluorescence results for samples taken post-drought upstream (b), adjacent (c) and downstream (d) of known straight pipe discharges in Newbern. Intensity is in Raman units. The red rectangle outlines the fluorescence region indicative of microbially-produced compounds and the black rectangle indicates humic, terrestrial fluorescence.

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Yang L, Han DH, Lee BM, Hur J (2015) Characterizing treated wastewaters of different industries using clustered fluorescence EEM-PARAFAC and FT-IR spectroscopy: Implications for downstream impact and source identification. *Chemosphere* 127:222-228. doi:10.1016/j.chemosphere.2015.02.028

J. NOTABLE AWARDS AND ACHIEVEMENTS. List any awards or recognitions for this research

No formal awards were received specifically for these findings during the project period. However, these findings did allow us to (1) apply for and win a fellowship to use the site inspection findings to build a GIS-based model of onsite wastewater status in the region and (2) present a webinar for the EPA Office of Decentralized Wastewater that was the highest attended since the webinar series began in 2010.

Dr. Elliott applied for graduate fellowship funding from the UA Council for Community-Based Partnerships (CCBP) to enable the use of the site inspection results for Hale and Wilcox counties and leverage them to model the status of onsite wastewater management in the Alabama Black Belt. Site inspection results will be used in conjunction with knowledge of local stakeholders, soil data and sociodemographic data. Dr. Elliott's graduate student Aaron Blackwell will be funded on the fellowship for academic year 2017-18. ArcGIS modeling expert Sagy Cohen (UA Department of Geography) is co-PI for the fellowship grant and will guide the modeling portion of the study.

Project findings were presented by Dr. Elliott for the EPA Office of Decentralized Wastewater webinar series on March 28th, 2017. The 90-minute webinar garnered the highest attendance in the history of the 2010-2017 EPA Decentralized Wastewater webinar series.

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	
Book Chapters	
Theses and Dissertations	
Water Resources Institute Reports	This report
Articles in Conference Proceedings	
Other Publications	

No written articles have been published to date. One article for submission to a refereed journal will be drafted this summer consisting of the results of the site inspection survey. Articles on water quality findings are also being planned.

L. PRESENTATIONS MADE:

- Elliott, Mark, Kevin White, Robert Jones, Parnab Das, Matthew Price, Zachary Stevens & Yuehan Lu. 2017. "Surface discharge of raw wastewater among unsewered homes in central Alabama" EPA Decentralized Wastewater Management Partnership. Webinar Series. 28 March 2017.
- Elliott, Mark, Kevin White, Robert Jones, Parnab Das, Matthew Price, Zachary Stevens & Yuehan Lu. 2016. "Direct Discharge of Household Wastewater in Rural Alabama - Scope and Impacts". Verbal presentation at UNC Water and Health. Chapel Hill, NC. 13 October 2016.
- Elliott, Mark, Parnab Das, Zachary Stevens, Aaron Miller & Yuehan Lu. 2016. "Investigating Septic System and Straight Pipe Impacts in the Lower Black Warrior River Watershed" First author and presenter. Oral presentation at Alabama Water Resources Conference and Symposium. Orange Beach, AL. 10 September 2016.

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	
Ph.D.	
Post Doc	

Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	One in progress
Ph.D. Dissertations	One in progress

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
	Biological Sciences
	Climate and Hydrological Processes
x	Engineering
	Ground Water Flow and Transport
	Social Sciences
x	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU

	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
X	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
X	WASTEWATER	WW
X	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: (Enter keywords of your choice, descriptive of the work)

Onsite wastewater management, straight pipes, untreated wastewater discharge, septic systems, non-point source pollution, rural poverty, streams, water quality, water pollution

Science and Policy of Environmental Instream Flows in the Tombigbee River Basin, Alabama and Mississippi: An Interstate Comparison

Basic Information

Title:	Science and Policy of Environmental Instream Flows in the Tombigbee River Basin, Alabama and Mississippi: An Interstate Comparison
Project Number:	2016AL178B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	AL007
Research Category:	Not Applicable
Focus Category:	Hydrology, Ecology, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Sarah Jean Praskievicz, Bennett Bearden

Publications

There are no publications.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE: Science and policy of environmental instream flows in the Tombigbee River Basin, Alabama and Mississippi: An interstate comparison
B. PRIMARY PI(s): Sarah Praskievicz, Ph.D., Assistant Professor
C. OTHER PI(s): Bennett Bearden, J.D., LL.M., J.S.D., Director of Alabama Water Policy and Law Institute and Associate Research Professor; Andy Ernest, Ph.D., P.E., BCEE, D.WRE, Professor and Department Chair
D. START DATE: March 1st, 2016
E. END DATE: February 28th, 2017
F. PROJECT OVERVIEW/SUMMARY: Alabama has abundant water resources in its rivers and streams, but those resources are not unlimited. The state is therefore vulnerable to water supply shortages during dry periods. Alabama's rivers and streams provide important benefits to society by providing for municipal and domestic supply, irrigation, and thermo-electric power. In addition to these withdrawals, however, water that remains in rivers also provides benefits, such as hydropower generation, navigation, recreation, aesthetic enjoyment, and environmental benefits. Although such benefits may be more difficult to quantify and economically valuate than water withdrawals, preserving Alabama's diverse and ecologically significant freshwater ecosystems is clearly a major priority for water-resource management in the state. With increasing water demand and uncertain future supply, Alabama's rivers are in danger of excessive withdrawals that would leave insufficient instream flows to meet environmental needs. Ensuring that adequate water is available to protect ecosystems is often accomplished through the designation of minimum flows that must be left instream and the enforcement of withdrawal limits, an approach that has been adopted as law by many states. For example, Alabama's neighboring state of Mississippi has adopted a legal minimum standard using the $7Q_{10}$ approach, which is defined as the average streamflow rate over seven consecutive days that may be expected to be reached as an annual minimum no more than one in ten years. Alabama currently has no environmental instream flow standard. Given the increasing stress to Alabama's water resources, the state would benefit from a more systematic and rigorous framework for determining the instream flows necessary to maintain species habitat in the state's rivers. Alabama has the unusual opportunity to build an environmental instream flow standard de novo. The lack of an existing standard can actually be an advantage, because Alabama can learn from the experience of other states and the success or failure of various approaches in protecting species and ecosystems. Through examination of the science and policy of environmental instream flows in Mississippi, it is possible to apply the lessons learned to develop a more effective environmental instream flow policy in Alabama. Instead of the application of a simple uniform metric like the $7Q_{10}$ approach, as in Mississippi, a more holistic approach could result in the determination of environmental instream flow requirements that are protective of particular species or ecosystems in particular rivers in Alabama. Given that all of Alabama's neighboring states currently have some sort of legally enforceable environmental instream flow standard, Alabama's lack of a standard places it at a

disadvantage in interstate water conflicts. This disadvantage is especially significant for interstate basins in which Alabama is the downstream state, including the Tombigbee River Basin, which has its headwaters in northeastern Mississippi but flows through western Alabama to join with the Alabama River to form the Mobile River. Flows through the Tombigbee system are therefore critical to sustaining freshwater inputs to Mobile Bay, which is highly productive ecologically and supports a commercially important shellfish industry. The Tombigbee River Basin is therefore a highly appropriate case study for interstate comparison of the science and policy of environmental instream flows.

G. PROJECT OBJECTIVE(s):

1. Conduct a systematic review of the legal and policy frameworks for environmental instream flows in Alabama and Mississippi.

2. Compile a geodatabase for the Tombigbee River Basin, including designated beneficial uses under the Clean Water Act and available hydrological and biological data that could be used to determine the instream flows necessary to preserve ecological function.

3. Analyze existing hydrological and biological data, with the goal of determining whether the implementation of a 7Q10 standard in Mississippi was effective in maintaining ecologically relevant hydrological parameters, and what the effects of such a standard would likely be in the Alabama section of the Tombigbee River Basin.

H. METHODOLOGIES: For Objective 1, we conducted a comprehensive review of published literature, case law, and statutory materials related to the laws and policies governing environmental instream flows in Alabama and Mississippi. We conducted a systematic interstate comparison of the reviewed material. The results of the review and comparison will be published in a report that we will distribute to policymakers and stakeholders.

For Objective 2, we created a geodatabase of the Tombigbee River Basin based on 12-digit Hydrologic Unit Code (HUC12) watersheds. We used the National Hydrography Dataset Plus Version 2 to associate river segments with each HUC12 watershed. We added information to the geodatabase about Clean Water Act designated beneficial uses for all assessed segments, availability of streamflow data from United States Geological Survey (USGS) gaging stations, and availability of data from biological surveys completed by the Geological Survey of Alabama (GSA), Alabama Department of Environmental Management (ADEM), Mississippi Department of Environmental Quality (MDEQ), and other agencies. One indicator that a river system is ecologically valuable is the presence of federally threatened or endangered species. We therefore incorporated into the geodatabase all designated critical habitat for aquatic and riparian species within the Tombigbee River Basin that are listed as endangered or threatened under the federal Endangered Species Act (ESA). In addition, we included the Strategic Habitat Units (SHUs), which are river segments selected by the United States Fish and Wildlife Service, Alabama Department of Conservation and Natural Resources, and Geological Survey of Alabama as focus areas for managing and restoring populations of rare aquatic species, because these river segments are geomorphically and hydrologically stable, have acceptable water quality and diverse substrate, and do not have significant populations of invasive species. The SHUs within the Tombigbee River Basin include ecologically valuable tributaries such as the Sucarnoochee River, Trussells Creek, Sipsey River, Lubbub Creek, Luxapalilla Creek, Buttahatchee River, Bull

Mountain Creek, North River, Upper Sipsey Fork, Locust Fork, and East Fork of the Tombigbee River. We also included data on physiographic provinces, lithology, soils, elevation, and land cover, which are all variables that could potentially be used in the classification of river segments within the Tombigbee River Basin.

For Objective 3, we analyzed the effectiveness of Mississippi's $7Q_{10}$ standard in preserving ecologically relevant flows. We calculated minimum environmental instream flows within the Alabama and Mississippi portions of the Tombigbee River Basin based on five historic flow methods. For each of the five historic flow methods, we calculated environmental instream flow thresholds based on the full gaging station record available for each of the 35 gages in the Tombigbee River Basin (going as far back as 1928). These thresholds were considered pseudo-standards for environmental instream flows. For all 35 stations, we then calculated the number of days (and proportion of total days in the record) from October 1st, 1985, to September 30th, 2014, on which discharge was less than the threshold associated with each historic flow method. These days can be considered the days on which the pseudo-standard for environmental instream flows would have been "triggered", or prompted some regulatory action, if that standard had actually been in effect. The rationale for selecting the 1985-2014 period is that 1) a thirty-year record provides a reasonably long period for examining variability over time and 2) 1985 was the year in which Mississippi's 7Q10 standard was adopted. Using 1985-2014 therefore allows us to examine the effectiveness of Mississippi's environmental instream flow standard, by demonstrating how often the standard would have triggered regulatory action if enforced perfectly.

I. PRINCIPAL FINDINGS/RESULTS: For Objective 1, we have completed the systematic review of the legal and policy frameworks for environmental instream flows in Alabama and Mississippi. Portions of the analysis are included in the publication that is in review at *River Research and Applications*. The entire analysis will be published in a report that will be made available to policymakers and stakeholders.

For Objective 2, we have compiled the geodatabase of the Tombigbee River Basin. It includes relevant geospatial, hydrological, and ecological data that can be used to support the development of environmental instream flow standards for the state of Alabama. The geodatabase is publicly available on ArcGIS Online.

For Objective 3, we have a paper in review at *River Research and Applications* on the comparative analysis of minimum environmental instream flows in the Alabama and Mississippi portions of the Tombigbee River Basin. We calculated the proportion of days in the 1985-2014 period on which discharge at each gaging station was less than each of the five historic flow thresholds. Averaged across all 35 gaging stations, discharge was less than the threshold set by the Tennant method on 37% of days. This percentage is higher than the 30% of mean annual flow threshold used in the Tennant method, indicating that there were more days in the 1985-2014 period than in the entire record with low flows in the Tombigbee River Basin. In contrast, the average proportion of days on which discharge was lower than the modified Tennant method, averaged across all gaging stations, was 25%, less than the 30% of mean monthly flow threshold. This result indicates that, although there were more low flows in the 1985-2014 period than in the entire record, the 1985-2014 period may have had higher flows during the low-flow season, thus reaching the 30% of mean monthly flow threshold less often. The flow threshold that was triggered next most frequently was the Q_{96} threshold, which had discharge less than that value 4% of the time, just as expected from the long-term flow duration curve. Finally, discharge was lower than the $7Q_{10}$ and $7Q_5(75)$ thresholds less than 1% of the time.

A single-factor ANOVA test revealed no significant differences between the Alabama and Mississippi gaging stations in the percent of days on which flows were lower than any of the five historic flow thresholds. This result indicates that differences in water policy between the two states did not translate into differences in low-flow frequency. A single-factor ANOVA test did, however, indicate significant differences between the headwater rivers and downstream rivers in the proportion of days in the record on which discharge was lower than thresholds defined by the $7Q_{10}$, $7Q_5(75)$, and Q_{96} methods. Discharge was lower than each of these three thresholds significantly more often on the downstream than on the headwater rivers (0.02 versus <0.01 for both $7Q_{10}$ and $7Q_5(75)$, 0.04 versus 0.03 for Q_{96}). For the Tennant and modified Tennant thresholds, there was no significant difference between the headwater and downstream rivers in the proportion of days in the record on which discharge was less than the threshold.

An ordinary least squares (OLS) regression analysis revealed that the number of days per year in which discharge was less than historic flow thresholds computed by the $7Q_{10}$, $7Q_5(75)$, and Q_{96} methods significantly increased from 1985 to 2014. There was no significant trend over time in the number of days per year in which discharge was less than historic flow thresholds computed by the Tennant and modified Tennant methods. This result suggests that the frequency of extreme low-flow events is increasing over time in the Tombigbee River Basin, but that there is no significant overall trend in discharge.

A one-factor ANOVA reveals significant differences among months of the year in the average proportion of days in the record on which discharge was less than the historic flow thresholds. On average across all five historic flow methods, the month in which discharge was most frequently less than the historic flow threshold was October (35% of the time) and the one in which it was least frequently less than the historic flow threshold was February (4% of the time). This result suggests that minimum discharge thresholds are most difficult to meet during dry periods of the year (i.e. fall) and easiest during wet seasons (i.e. winter).

J. NOTABLE AWARDS AND ACHIEVEMENTS: NA

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	1 (in review)
Book Chapters	
Theses and Dissertations	1 (in progress)
Water Resources Institute Reports	
Articles in Conference Proceedings	

Other Publications	

Praskievicz, Sarah, Cehong Luo, Bennett Bearden, and Andrew Ernest; 2017, Evaluation of historic flow methods for determining minimum environmental instream flow requirements: Tombigbee River Basin, Alabama and Mississippi, *River Research and Applications*, in review.

Luo, Cehong; 2018, Examining potential impacts of external drivers on environmental instream flows on the Cahaba River, "MS Dissertation," Department of Geography, University of Alabama, Tuscaloosa, AL.

L. PRESENTATIONS MADE:

Praskievicz, Sarah, 2016, Science and policy of environmental instream flows in the Tombigbee River Basin, Alabama and Mississippi: An interstate comparison, Alabama Water Resources Association Meeting, Orange Beach, AL.

Praskievicz, Sarah, 2016, Instream flows, panel presentation at the Water Policy Summit, Tuscaloosa, AL.

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	1
Ph.D.	
Post Doc	

Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	1 (in progress)
Ph.D. Dissertations	

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
X	Biological Sciences
X	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
X	Social Sciences

	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
X	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
X	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
X	LAW, INSTITUTIONS, & POLICY	LIP
	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW

	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: instream flow, ecosystems, policy analysis, rivers, channels, law

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	4	0	0	0	4

Notable Awards and Achievements